
Use of Functional Electrical Stimulation Cycle Ergometers by Individuals With Spinal Cord Injury

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Purpose: To assess the use of network-connected home-based functional electrical stimulation (FES) cycle ergometers. **Method:** De-identified data on >20,000 FES sessions for 314 users with spinal cord injury were analyzed for usage patterns and energy expenditure. These were compared with authoritative exercise guidelines of 150 minutes of moderate-intensity aerobic activity per week over at least 2 days per week for a total of 1,000 kcals. **Results:** Seven percent of participants were classified as high- (≥ 5 days/week), 11% as medium- (2-5 days/week), and 82% as low-frequency users (<2 days/week). **Conclusion:** None of the users satisfied authoritative energy expenditure recommendations for disease prevention with FES cycling alone. **Key words:** exercise guidelines, functional electrical stimulation, health and fitness guidelines

The combination of physical activity undertaken through intentional exercise and nonexercise physical activity is widely reported to have salutary effects on the cardiocirculatory, musculoskeletal, and cardioendocrine systems. Benefits of physical activity on these body systems and on overall health have been based upon satisfying various criterion thresholds, including numbers of days per week in which moderate to vigorous activity is undertaken, weekly caloric expenditure, or minutes engaged in physical activity. Depending on the health benefits being targeted, these guidelines have become authoritative benchmarks used by clinicians to encourage compliance with prescriptive exercise conditioning guidelines. For maintaining a healthy lifestyle, the US Department of Health and Human Services Centers for Disease Control and Prevention (CDC) and the American College of Sports Medicine (ACSM) have defined a need for adults to undertake at least 150 minutes of moderate-intensity aerobic activity per week over a span of at least 2 days per week, exerting a weekly total of 1,000 kcals.^{1,2} This healthy lifestyle is generally believed to slow the trajectory of all-

cause cardiovascular and endocrine disease that is commonly associated with human aging.

It is widely reported³⁻⁵ that people with neurological impairments such as spinal cord injury (SCI) experience significant decline in overall fitness, in some cases due to the physical impairment itself and in other instances because of barriers imposed on access to reconditioning exercise. Notwithstanding the cause, sustained programs of conditioning exercise can address physical deconditioning and deconditioning-associated secondary medical complications. In cases where neurological injury or disease limits the potential for voluntary muscle activation, electrical current is administered to the skin surface and used to stimulate muscle contraction. These contractions can then be sequenced under microprocessor control to initiate purposeful movement including cycling and ambulation. Multiple studies (reviewed in Hunt et al⁶) have reported on the benefits of functional electrical stimulation (FES) cycling, including improved muscle strength/volume, enhanced glucose metabolism, and reduced spasticity.⁷ Benefits for the cardiovascular, pulmonary, and immune

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system functions and, in some cases, an increase in bone mineral density have also been reported.^{7,8}

Commercial FES cycling systems first became available in the mid 1980s and have since been adapted and deployed for home use. Habitual use of these devices is necessary to achieve discernable health benefits, but exercise compliance in the general population is often poor,⁹ even when exercise is medically prescribed for life-threatening conditions.⁸ Given the poor adherence to exercise in general, a detailed look at usage patterns for home FES cycling units seems warranted.

The purpose of this study was to examine home-based FES cycle usage patterns by people with SCI. We hypothesized that most people engaging in home-based FES cycling would fall below recommended exercise standards for targeting cardioendocrine disease if FES cycling was their sole physical activity.

Methods

Data acquisition

A securely transmitted de-identified dataset that was limited to home-based users and use profiles for RTI-brand FES cycle ergometers was obtained from Restorative Therapies, Inc. (RTI), a company that markets an FES cycle for clinic and home use. The dataset was compiled from home-based wireless networks or Ethernet connections and yielded information from 314 users with SCI who engaged in 20,183 activity sessions. Each activity session was logged with the date, time, duration (seconds), energy expenditure (joules), and distance cycled.

Data modification and analysis

All data were examined for completeness before analysis was undertaken. Data could not be verified for 6 users representing 311 FES sessions. Thus, the final analysis was performed on 308 users undergoing 19,872 sessions. To determine adherence, the average days per week and minutes per week were calculated for each of the 308 participants, who were grouped according to frequency of usage. Frequency usage was operationally defined as low (<2 days a week),

Table 1. Average use for each exercise classification

Exercise frequency	No. (%) of participants	Average use	
		days/wk	min/wk
High	7 (2%)	6.3 ± 1.0	672 ± 621
Medium	83 (27%)	3.1 ± 0.7	118 ± 50
Low	218 (71%)	0.9 ± 0.4	34 ± 21

medium (2-5 days a week), and high (≥5 days a week). All data (including caloric expenditure) are part of the general output created by the ergometer software.

Results

Most users were classified in the low-frequency category (71%) (**Table 1**); the average usage for this category was 0.9 ± 0.4 days or 34 ± 21 min/wk, well short of the recommended 150 min/wk. Medium-frequency users (27%) also did not reach recommended levels, but high-frequency (2%) users did (**Table 1**). None of the participants met the energy exertion requirement of 1,000 kcals/wk, with a maximal weekly expenditure of 43 kcals.

Conclusions

The key findings of this study are that usage frequency of home-based FES cycling is below recommended levels for weekly use and caloric expenditure is below the recommended levels for the majority of persons with SCI. This assumes that:

1. The FES usage goal for referring professionals and users is the reduction of cardiovascular and metabolic disease and not other benefits that are previously reported for the modality, eg, muscle hypertrophy, enhanced blood flow, or improved self-image;
2. FES cycling is the sole source of caloric expenditure; and
3. Estimates of caloric expenditure reflect actual energy usage.

Our findings allow for the possibility that FES cycling is only part of a larger activity plan that encompasses other intentional exercise and nonexercise physical activity. If so, we are unaware

whether health care professionals who were prescribing and supervising the FES programs had advised users of exercise targets for broader health preservation. It is also worth noting that about half of people with SCI (who comprised the majority of participants in this study) typically report performing no physical activity whatsoever,^{10,11} in which case usage patterns observed in the current study might actually be considered substantial by comparison and uniquely resulting from the use of an FES exercise mode.

The study findings do not exclude the possibility that the guidelines for persons with SCI are overreaching. The greatest benefits obtained from exercise are achieved by persons at the lowest end of the fitness continuum and for whom even small increases in activity result in significant benefits.¹² Thus, health benefits in the most deconditioned study users may approach those of active individuals with moderate to high fitness levels who better adhere to the guidelines.¹²

Among the novel findings of this study was the exceptionally low caloric expenditure of FES cycling reported in the database. The model adopted for this estimation is based upon pedal torques and pedaling distance sensed by the units, but it disregards the incorporation of energy utilized in the maintenance of basal body functions, energy expended in body movement(s)

not translated to the pedals, increased energy output involved in activity-induced respiratory and cardiovascular functions, and excessive postexercise oxygen consumption. We feel that this model needs to be examined to determine whether health care providers are receiving a full accounting of their patients' energy utilization. That stated, it is known that even passive exercise is better than no exercise at all and that passive cycling has benefits for persons with SCI.¹³

Overall, we find that users of home-based FES cycling are below authoritative standards for overall health maintenance. This is correctable through better education of users on these targets and clarification of patient-specific goals that are established between health care providers and end users. At the least, these professionals should be aware that adjunctive exercise through alternative intentional exercise and encouraged nonexercise physical activity should also be incorporated in the long-range health plan.

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